

NANOTECHNOLOGY: A VAST FIELD FOR THE CREATIVE MIND

By

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Code 562

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A KEYHOLE LOOK AT THE UNIVERSE: HST

THE Hubble Space Telescope (HST) is a large space-based telescope that has provided us with a keyhole view of the universe. It has allowed us to see the most distant galaxies, the birth of stars, and the structure of the universe.



A KEYHOLE LOOK INTO THE NANOCOSMOS

- Scanning Electron Microscope (SEM)
- Transmission Electron Microscope (TEM)
- Atomic Force Microscope (AFM)

SOCIETAL IMPLICATIONS

- Knowledge base: better understanding of nature and life in general
- New products: ~\$1 trillion/year by 2010-2015. Will require ~2 million nanotech workers.
- Improved healthcare: extend life-span, its quality, human physical capabilities
- Sustainability: agriculture, food, water energy, materials, environment

NANOPEN



Words written on a silicon substrate using a carbon nanotube tip of about 10 nanometers in diameter. The thickness of the letters is about 7-8 nanometers, and the height of the letters is 20 nanometers. The words were imaged with an atomic force microscope equipped with another nanotube tip.

Credit: Ramsey Stevens, Lance Delzeit and Cattien Nguyen of NASA Ames Research Center

WHY IS NANOTECHNOLOGY IMPORTANT?:

Just Imagine:

- molecular-sized machines that float in your bloodstream, carving away arterial plaque, fighting viruses — and perhaps ending disease forever
- invisible surveillance devices that provide battlefield intelligence, monitor industrial processes — or track political dissidents
- agriculture nanobots that run super-productive farms, or solar-energy-conversion nanobots that provide essentially free energy
- nanocomputers and nano-storage devices that open a world where most human productivity moves online
- Or, maybe, self-replicating machines that might just keep replicating until they overwhelm our ability to control them, burying us in a "gray goo" (oops) Depends on whom you listen to: the boosters or the doomsayers. In any case, nanotechnology has the potential to change society in ways we can now only begin to predict.
- From: www.nanospot.org/

NANOTECHNOLOGY ROADMAP

- First stage, ~2001: passive nanostructures in coatings, nanoparticles, bulk materials (nanostructures metals, polymers, ceramics)
- Second stage, ~2005: active nanostructures such as transistors, amplifiers, targeted drugs and chemicals, actuators, adaptive structures
- Third stage, ~2010: 3D nanosystems with heterogeneous nanocomponents and various assembling techniques; bio-assembling; networking at the nanoscale and new architectures
- Fourth stage, ~2020: molecular nanosystems:
- With heterogeneous molecules, based on biomimetics and new designs

MEMBERS OF THE NATIONAL NANOTECHNOLOGY INITIATIVE

WHITE HOUSE

Office of Science and Technology Policy (OSTP)
National Science and Technology Council (NSTC)

Departments

DOC/NIST, DOD,
DOE, DOJ, DOS,
DOT, DOTreas, USDA

Independent Agencies

EPA, FDA, NASA, NIH, NRC,
NSF, USG

HUMAN RESOURCES

Engineers:

Electrical, materials, electronic, electrical,
chemical, mechanical

Chemists:

Physical, organic, analytical, biochemical,

Physicists

Biologists

DEVELOPMENTS IN THE FIRST TWO YEARS

(NNI, 2001-2002)

- Faster than expected, reducing the time of reaching commercial prototypes by at least a factor of two for several key applications
- 10 key developments:
 - Engineer materials with atomic precision using biosystems as agents
 - Create circuits with the logic element a molecule wide
 - Assemble DNA, nanocrystals to build molecular devices and systems
 - Detect anthrax, other contaminants with unprecedented speed
 - Single molecule behavior and interaction
 - Artificial genetic system
 - Conducting polymers
 - New concepts for large scale production of nanotubes, their use
 - Drug delivery systems
 - Detection of cancer

AREAS IN NANOTECHNOLOGY

- Nanoelectronics
- Energy conversion and storage
- Communications
- Biomedical
- National Security
- Space exploration
- Agriculture
- Stronger and lighter structural materials

NATIONAL NANOFABRICATION USERS NETWORK (NNUN)

<http://www.nnun.org>

- The mission of NNUN is to provide the nation's researchers with effective and efficient access to advanced nanofabrication equipment and expertise
- Consists of two hub facilities on the east and west coasts at Cornell University and Stanford University and the University of California at Santa Barbara
- In the past seven years the NNUN has served users from 40 states and 12 foreign countries. In 2002, nearly 2000 users , a large number of who are graduate students, used NNUN facilities in performing their research.

SOME EXAMPLES OF RESEARCH PERFORMED THROUGH NNUN

- Adhesive based on Gecko Toes
Gecko have the ability to cling to vertical surfaces however smooth. It's foot may have nearly 500K setae each of which terminates in bundles containing hundreds of nanoscale spatulate structures.
Nanofabricated synthetic setae show adhesive forces that are consistent with gecko's.

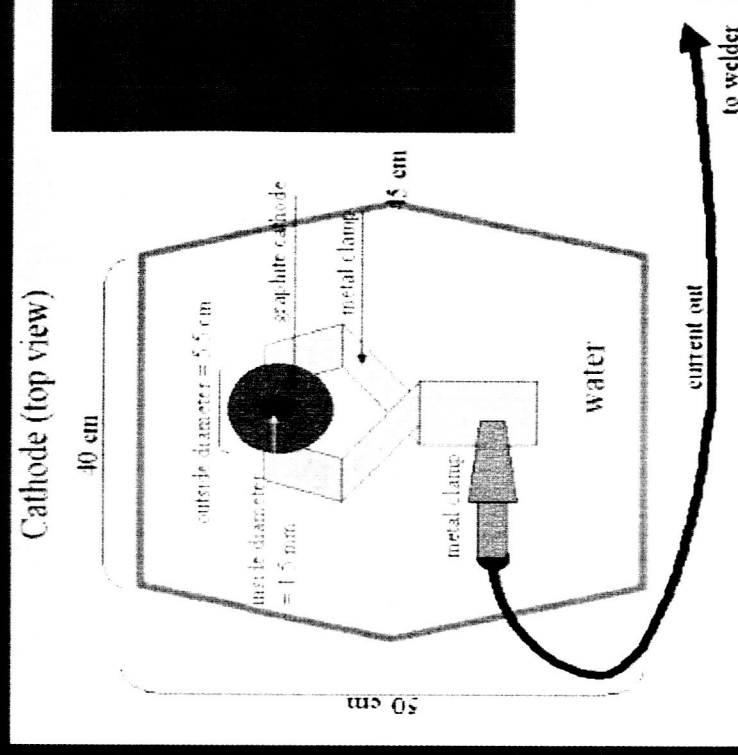
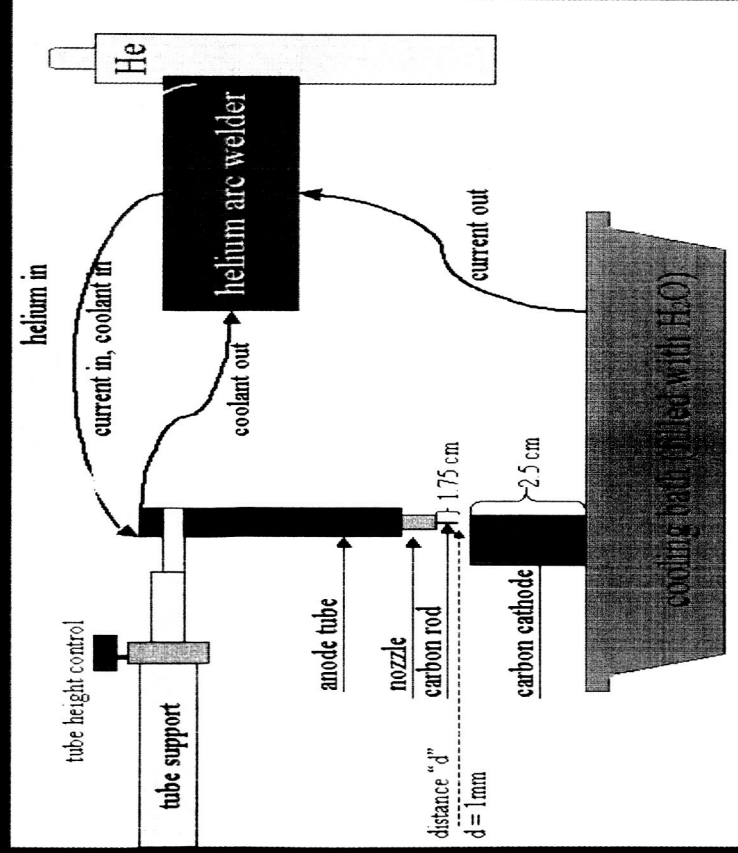
Autumm K., et al., Proc. Natl Academy Science, **99**, 12252 (2002)

- Ion channels and lipid bilayer membranes under high potentials using microfabricated apertures, D.M. Bloom et al.
- Nanocalorimetry of polymers and metals, L.H. Allen, Univ of Illinois
- Single atom single electron transistor, J. Park et al.
- High speed atomic force microscopy, Quate et al.
- 1.55 μm and 1.3 μm microcavity light source, P.K. Bhattacharya, Univ. of Michigan
- Bipolar transistors for 140-220 GHz Amplifiers, M. Rodwell, UCSB
- Gain Cell for charge sensing, A. Gokirmak and S. Tiwari (Cornell Univ.)
- Case study: charge sensing
- Elasticity of actin filament using nanofabricated cantilevers, G.H. Pollack, Univ. of Washington
- Single cell detection using mechanical oscillations, H. Craighead (Cornell)
- High density chip for proteomics (protein binding assays), P. Wagner et al.

- Artificial silicon retina (ASR), Chow et al. (optobionics)
- Micro-machined flow probe (blood flow monitoring system), C.J. Drost et al. (Transonic Systems)
- Integrated sampling devices for bioanalysis, W.H. Smart (Kumetrix)
- Micro volume field-effect pH sensor for scanning probe microscope, C. Quate et al., Stanford
- Integrated optics for chip-based electrophoresis, F. Lytle, Purdue Univ.
- MEMS for studying insect biomechanics, M. Bartsch, Stanford
- A sensor system to measure contact stress distributions in the human knee, M. Hull, UC-Davis
- Properties of small scale magnetic structures, Jun Yu and Andy Kent, NYU
- Deformable silicon nitride mirrors for focus control, David Dickensheets (Montana State Univ.)

- Torsional Magnetometer, M.J. naughton (Boston College)
- Spin-polarized light emitting diodes, D. Awschalom (UC-Santa Barbara)
- Micro-fabricated X-ray optics, K. Fikelstein et al. (Cornell)
- MEMS technology for advanced imaging systems, Alex Tran, Xerox
- High speed large bandgap transistors and circuits, L.F. Eastman et al.
- Nano-magnetics: spin-torque effects, D.Ralph et al. , Cornell
- Silicon 3D electronic integration, L. Xue, C. Liu and S. Tiwari, Cornell
- Multifunctional scanning force microscope tips, Andreas Koglin, Kjoern Rosner, Dan van der Weide, U. Wisconsin
- Carbon based nanostructures (field emitters using CNT's), M. Guillorn & M. Simpson (U. Tenn.)
- Power adaptive electronics: back gated transistors, S. Tiwari et al.
- Surface sensitized schottky barrier solar cells, G. Stucky, UC Santa Barbara

GODDARD'S SYNTHESIS METHOD FOR CARBON NANOTUBES: SET-UP



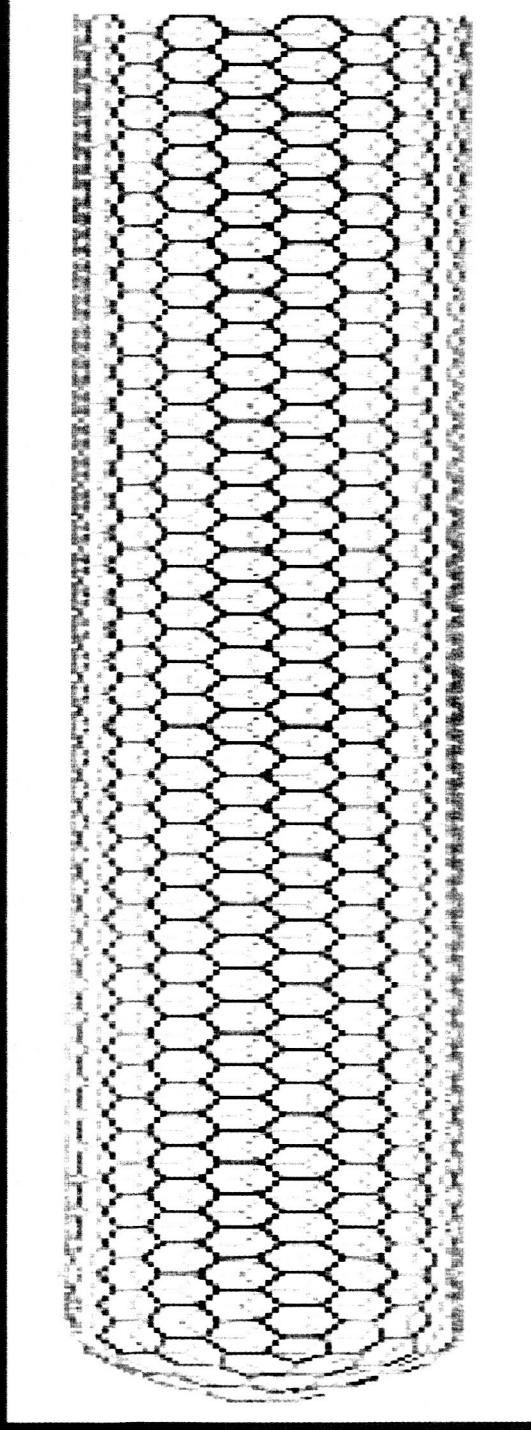
SINGLE WALLED CARBON NANOTUBES (CNT's): Properties

- Small ropes of SWCNT, some MWCNT
- Average dia. ~30nm for bundles, and ~2nm for individual CNTs
- Average apparent length ~10 μm
- Maximum Tensile Strength ~100GPa
- Thermal Conductivity ~2000 W/m/K
- Resistivity = $.34\mu\Omega^*\text{m}$
- Young's Modulus (SWNT) ~ 1 Tpa

NANOTECHNOLOGY

ATOMS → MOLECULES → SMART SYSTEMS

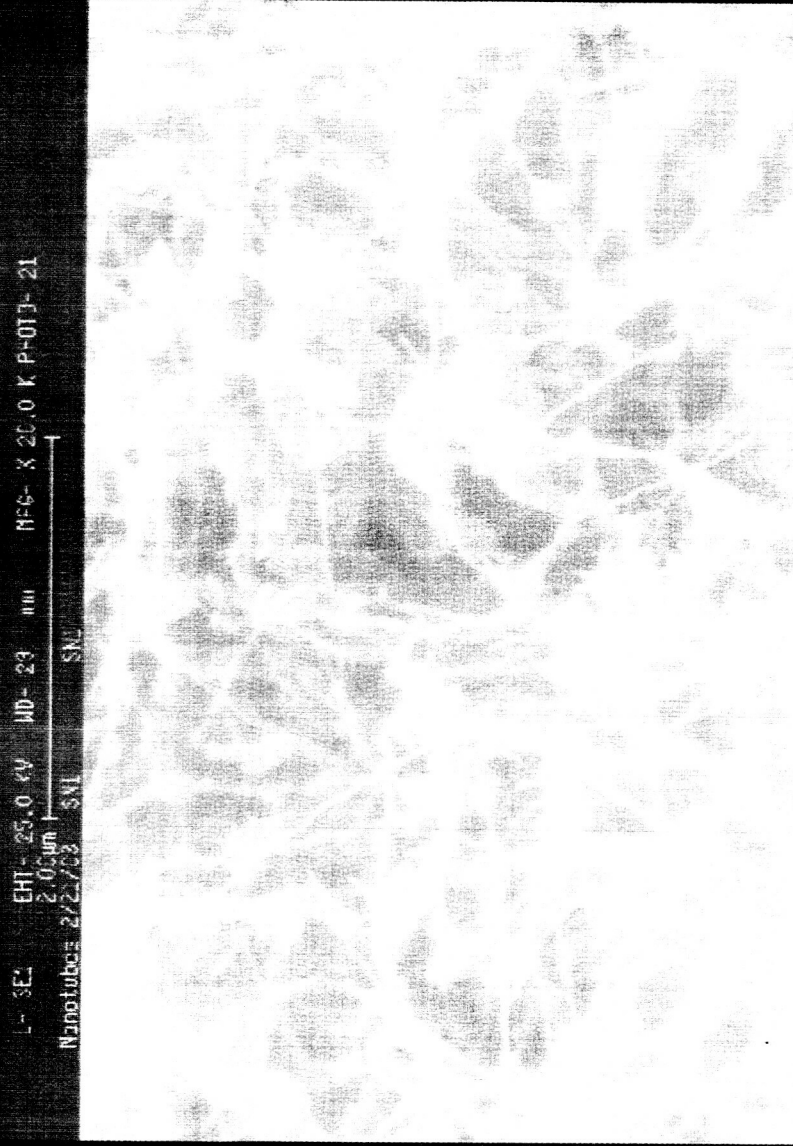
CARBON NANOTUBES: A Molecule from Science Fiction



SOME APPLICATIONS OF CNT'S

- Storage medium for hydrogen and other gases
- Electron field emitters in Field Emission Displays
- Additive in polymer and metal composites
- Templates for nanowires
- Microtips for scanning probe microscopy
- Electrical and heat conductors in nanocircuits
- Radiation shielding materials for use in space
- Solar sails
- Batteries
- Sensors

SCANNING ELECTRON MICROSCOPE (SEM) IMAGE OF CARBON NANOTUBES



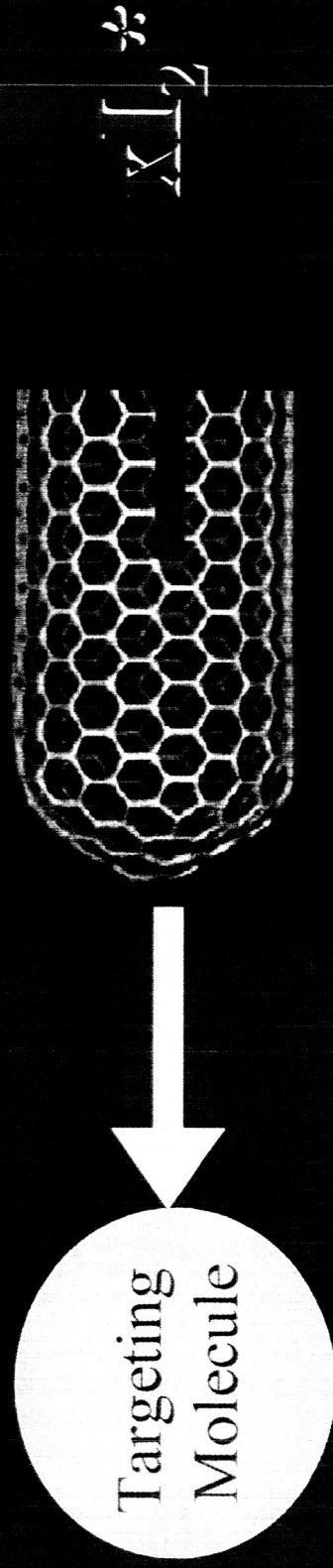
NANOTECHNOLOGY Definition on:

http://nano.gov/omb_nifty50.htm

- Working at the atomic, molecular and supramolecular levels, in the length scale of approximately 1-100 nm range, in order to understand and create materials, devices and systems with fundamentally new properties and functions because of their small structure

CANCER TREATMENT USING CNT's: GSFC-NCI

- I_2^* will be introduced into CNT's by capillarity and thus contained
- Cancer targeting smart organic molecule and/or chemotherapy drug will be bound chemically to CNT's.

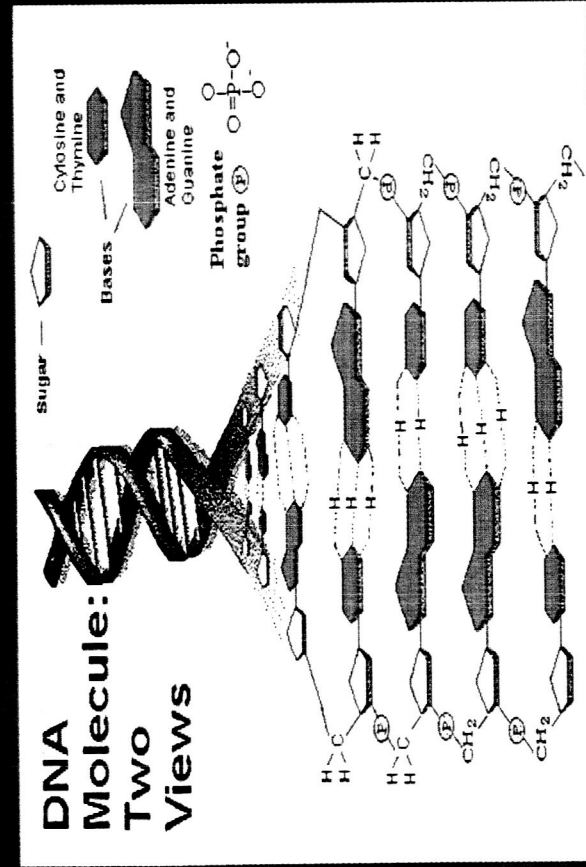


CHARACTERISTICS OF GSFC'S SYNTHESIS METHOD FOR CNT'S

- No Metal Catalyst (H_2O , amorphous carbon)
- Open System
- Low cost/gram ~ \$10 (compared to \$500/gram)
- Easy to scale-up
- Good yield (~90% SWCNT's)
- Low amperage ~25A (compared to 60 A)

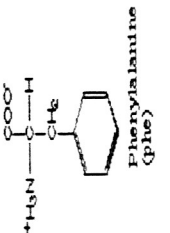
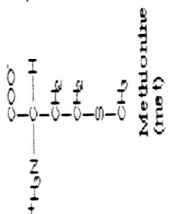
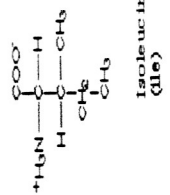
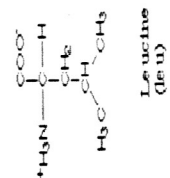
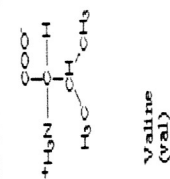
MACROBIOMOLECULES

DNA

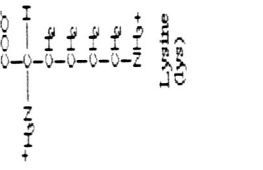
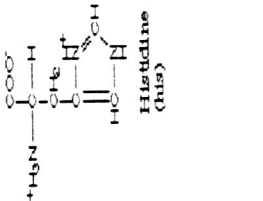
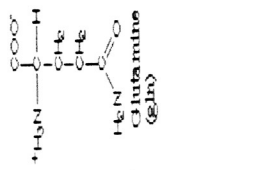
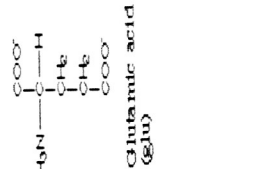
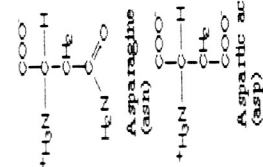


BUILDING BLOCKS AMINO ACIDS

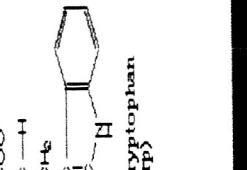
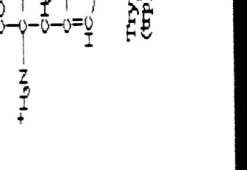
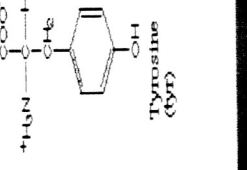
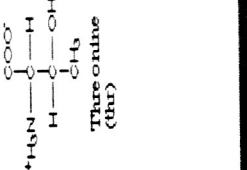
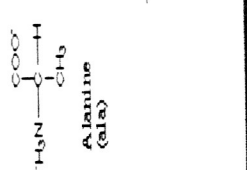
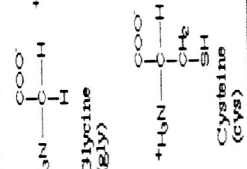
Amino acids with hydrophobic side groups



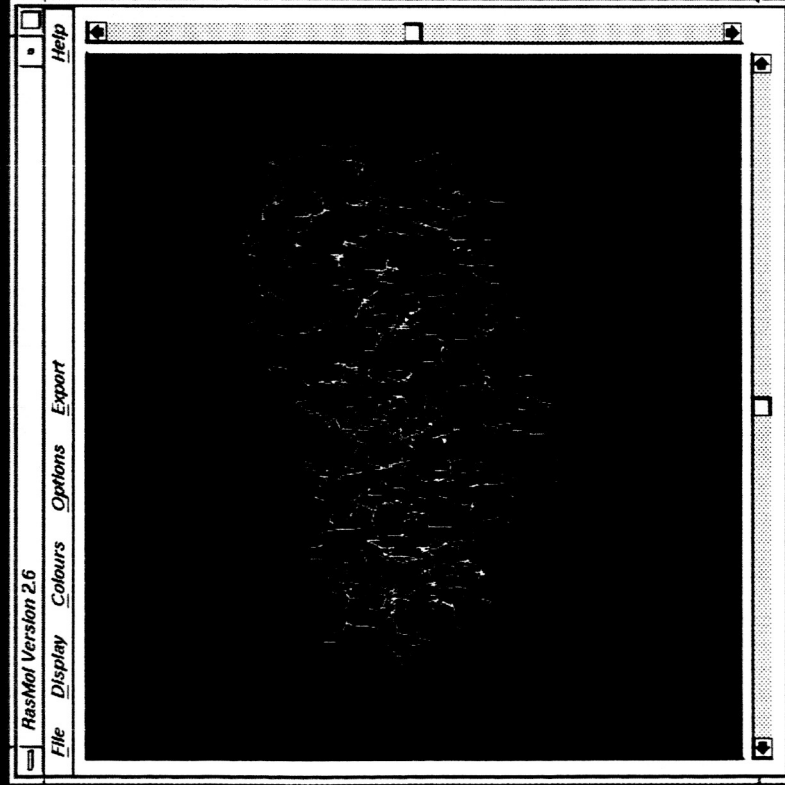
Amino acids with hydrophilic side groups



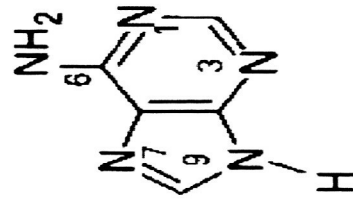
Amino acids that are in between



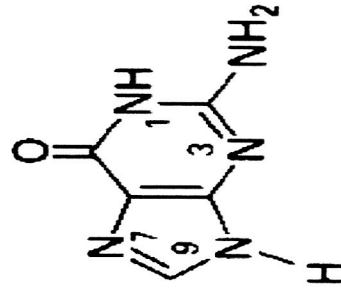
PROTEINS: ENZYMES



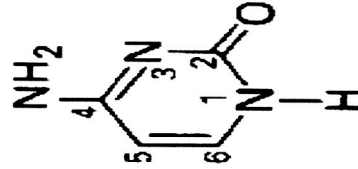
NUCLEIC ACIDS



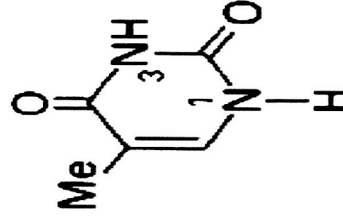
adenine



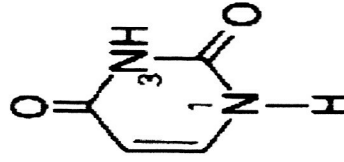
guanine



cytosine



thymine



uracil

HISTORY OF CARBON NANOTUBES

- Carbon nanotubes are fullerene-related structures which consist of graphene cylinders closed at either end with caps containing pentagonal rings. They were discovered in 1991 by the Japanese electron microscopist Sumio Iijima who was studying the material deposited on the cathode during the arc-evaporation synthesis of fullerenes. He found that the central core of the cathodic deposit contained a variety of closed graphitic structures including nanoparticles and nanotubes, of a type which had never previously been observed. A short time later, Thomas Ebbesen and Pulickel Ajayan, from Iijima's lab, showed how nanotubes could be produced in bulk quantities by varying the arc-evaporation conditions. This paved the way to an explosion of research into the physical and chemical properties of carbon nanotubes in laboratories all over the world.

A NANOTECHNOLOGY LABORATORY: Synthesis of Proteins

